# Epidemiology and demand for healthcare: an agent-based simulation model

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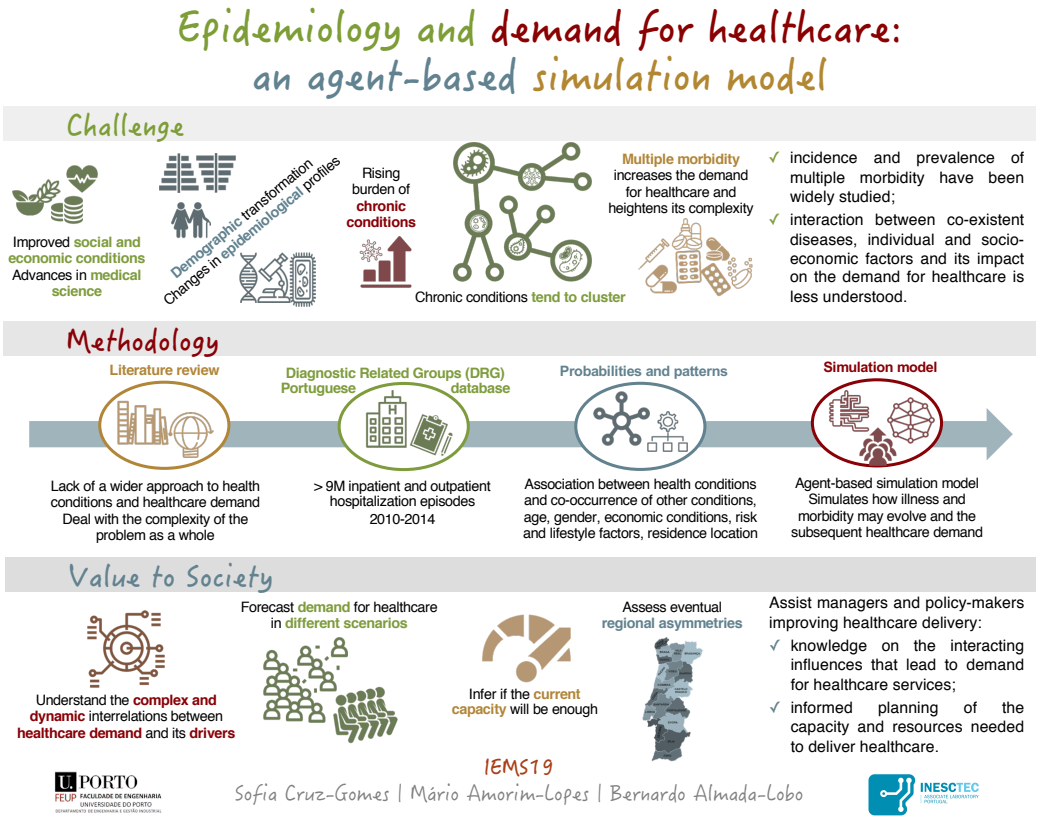


## 1 The Challenge

In the last decades, the improved socio-economic conditions and the advances in medical science led to significant improvements in health and longevity, responsible for a significant demographic transformation and a subsequent drastic change in the epidemiological profiles and in the patterns of health and illness.

Chronic diseases are now the world's leading cause of death, and their burden is increasing rapidly. As the prevalence of chronic conditions continues to rise, several attempts to understand the main causes and consequences of these epidemiological changes have been made. The prevalence of the most common chronic diseases and the main factors on which they depend is now known. It has been shown that increases in the prevalence of chronic diseases rise the demand for healthcare and generate new challenges on ensuring the delivery and financing of healthcare services. Furthermore, it is known that chronic conditions tend to cluster, as people with one chronic condition are more likely to also have others.

Although the prevalence of multiple morbidity and its impact on healthcare demand have been widely studied, the complex interaction between multiple co-existent diseases, demographic and socioeconomic

factors and its impact on the demand for healthcare services is less understood. The methods used to understand and predict the epidemiological evolution evolved from simple state-transition and statistical methodologies to more complex epidemiological models. Typically, the former analyze and forecast the incidence and prevalence of specific diseases, while the latter aim to represent the complex epidemiology of disease occurrence and its association with a range of related factors and processes. Due to the complex nature of the interaction between epidemiology and several individual, social and demand-related factors, computational models and simulations are now seen as central research tools in epidemiology.

Through an empirical analysis for Portugal, we aim to develop an agent-based simulation model to explain and forecast the epidemiological conditions and subsequent healthcare demand, accounting with the evolution of several drivers. Our approach differs from previous studies by addressing five main limitations of the existent approaches. First, the analysis of multiple co-existent conditions is usually made considering only the chronic conditions, and a better understanding on the interaction between chronic and non-chronic disease is also of major interest. Second, most of the studies intended to provide knowledge for a specific disease (or group of diseases) and its association with other conditions that are previously known to be related, which can hide less obvious relations between conditions. Third, studies dedicated to the analysis of coexistent diseases and their evolution over time consider a simple count of conditions or, more succinctly, if the individual has or not two or more chronic diseases at the same time. Forth, studies analyzing longitudinal changes in morbidity over time and through the life course are limited, as well as analysis considering cohorts effects on the co-existence of health conditions. Finally, most of the research is only focused on the analysis of historical data and does not go further in assessing for the future healthcare services demanded to contribute to a more informed planning. To the best of our knowledge, no such application of a similar approach to epidemiology and healthcare demand exists.

## 2 The Methodology

In order to tackle this problem, we started by reviewing the key literature on the demand for healthcare and on epidemiologic models for a deeper understanding of the scope, advantages and limitations of the assorted theories and approaches. The literature reviewed pointed to several topics worthy of investigation, where it stood out the lack of a wider approach to health conditions and healthcare demand, capable of dealing with the complexity of the problem as a whole. Among the more advanced epidemiological models that may be able to deal with the intricacy of the problem, agent-based modeling is recognized as a promising approach to model the complex interactions and processes related to health conditions. Although this type of models has been applied to single chronic diseases, it is still underused among researchers and a broader use of agent-based modeling to provide insights on population health and consequent demand for healthcare services and resources is missing. Identifying the main research gaps enabled us to define the direction of our research and frame our contribution.

Using data from the Portuguese Diagnostic Related Groups database (Base de Dados Nacional de Grupo de Diagnóstico Homogéneo) we constructed a dataset with information on more than 9 million inpatient and outpatient hospitalization episodes in the period 2010-2014.

Historical data was used to infer about the probabilities and patterns on the evolution of health conditions through their association with the co-occurrence of other current or previous chronic and non-chronic conditions, as well as of other relevant factors, such as age, gender, economic conditions, risk and lifestyle factors and residence location.

These patterns were then used in the development of an agent-based simulation model (ABM) that simulates how illness and morbidity may evolve and the subsequent healthcare demand, using projections for some relevant variables (e.g., demographic) and considering specific 'what if' scenarios (e.g., change in the prevalence of a specific condition).

Furthermore, the results on the expected healthcare demand were used to infer whether the current physical capacity will be enough to provide the expected volume of healthcare services and for the assessment of eventual regional asymmetries.

# 3 The value to Society

There are many factors driving the demand for healthcare services. Nowadays, in a context of rising coexistence of multiple health conditions, it is recognized that epidemiological factors are extremely relevant on driving the decision to seek for care. Moreover, a higher prevalence of multiple conditions increases the demand for healthcare services and heightens its complexity. Thus, a deeper analysis of the interacting influences that lead to the complex pattern in the use of health services, addressing the evolution on morbidity patterns and planning for the needs of the different types of healthcare services is of most importance.

Our approach represents an effort to better understand these patterns of demand, specially focusing on the impact of the evolution of multiple diseases co-existence over time and across people from different contexts and with different individual characteristics.

Hence, with the study of probabilities and patterns on the evolution of health conditions and the development of this simulation model we hope not only to make a scientific contribution to the field, but also to assist health managers and policy-makers improve healthcare delivery. By providing a tool that enhances the understanding of the complex and dynamic interrelations between healthcare demand and its main drivers and produces accurate forecasts on healthcare demand, we aim to contribute to a more informed planning of the capacity and resources needed to deliver healthcare, and to a better knowledge on epidemiologic trends and regional disparities.